Analysis of the Hand-held Sunphotometer

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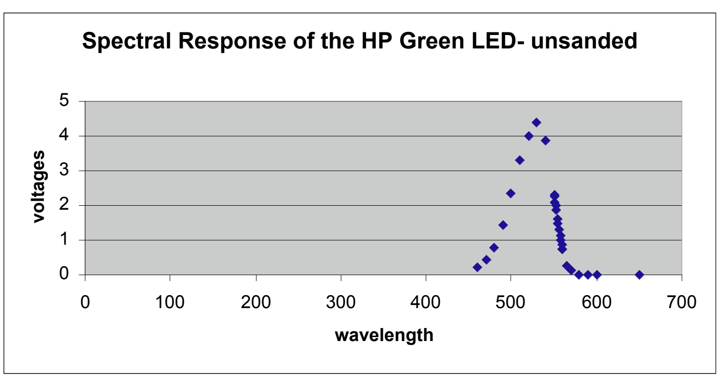
Spring 2000

Background

Aerosols are tiny particles in an aqueous or gas suspension. These aerosols have a definite impact on climate, but scientists are not sure of what this impact is. Aerosols could cool the atmosphere or warm it. In addition, there are also various health and environmental consequences associated with aerosols. A challenge evolves when trying to measure aerosols. Satellites measure the aerosol over oceans by reflected light, but do not necessarily give an accurate description of the aerosol over land. The ocean surface is basically dark while the land surface is brighter and more spatially variable. Therefore, the fractional contribution of aerosol to the reflected light is larger than that over land. This is the job of a sunphotometer. A sunphotometer measures the optical thickness of the atmosphere and aerosol by measuring the column of air that a beam of sunlight passes through. Although a sunphotometer measures the optical thickness of aerosol, it can not accurately describe how spatially and temporally variable aerosols are. The density of an aerosol over a certain area is very heterogeneous and their life span in the atmosphere is on the order of a few days to several weeks. The effects of aerosol loading is not very well known, but plays an important piece in the general scheme of the earth. Understanding the forcing due to aerosols, along with clouds, methane, and other contributors, can give an accurate picture of the forcing of aerosols and how the earth is changing in general. The increased popularity of land based aerosol measuring networks (like AERONET at the Goddard Space Flight Center's CIMEL network and the SIRN network) is that they can be used as a "check" for the retrievals of the Terra instruments (satellites like MODIS and CIMEL).

The Hand Held Sunphotometer

Aerosols pose a problem from a measurement standpoint because aerosols are spatially and temporally variable. In addition, the costs of land- based sunphotometers are high; the MFRSR and CIMEL instruments are \$10,000 and \$20,000 respectively. Also, these sunphotmeters measure the aerosol at a point, but a satellite sees the average of the aerosol amount over several kilometers. Hand held sunphotometers solve the problem of the fickle nature of aerosols. Students and "hand-helds" can be used to see whether or not the aerosols are variable over the kilometer scale. High school students across New York City took measurements with a little sunphotometer with one photodetector (analogous to the six photodetectors on a professional sunphotometer) by aligning the sunlight on the photodetector and noting the voltage reading a voltmeter which is attached to it.

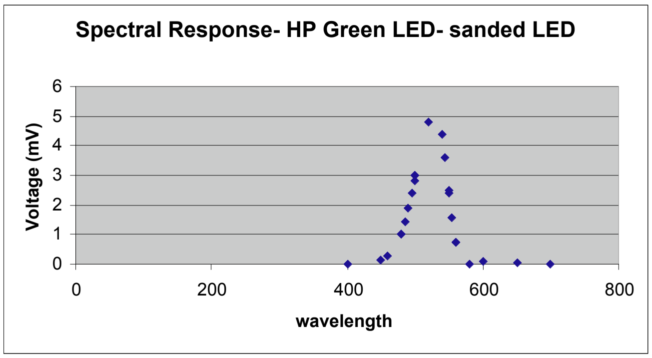


Using Beer's Law ($V = V_0 e^{-mT}$, where m is the airmass and T is the optical thickness) and a spreadsheet which calculates the natural logarithm of the voltage and airmass, we can make a Langley Regression. A Langley

Regression is the least-squares regression of the plot of the natural Logarithm of the voltage vs. air mass.

Building and testing

Building the "hand helds" was a challenge. Fifty hand- helds were made. We decided not to sand down or polish the LED (Light Emitting Diode, which acts as a photodetector) because we thought that there might be error due to sanding. To test the LED, a series of tests were done to examine the spectral response of the LED. A spectral response curve was generated for a sanded LED and an unsanded LED to see any differences. We also tested the hand-helds with and without the sanded LED and we noticed that sanding the LED decreased the transmission through the LED. Therefore, we decided to go with the unsanded LED, since it maximized the transmission and the voltage output. However, we did not consider the potentially greater sensitivity of the unsanded LED to instrument alignment due to the increased surface area of the detector.



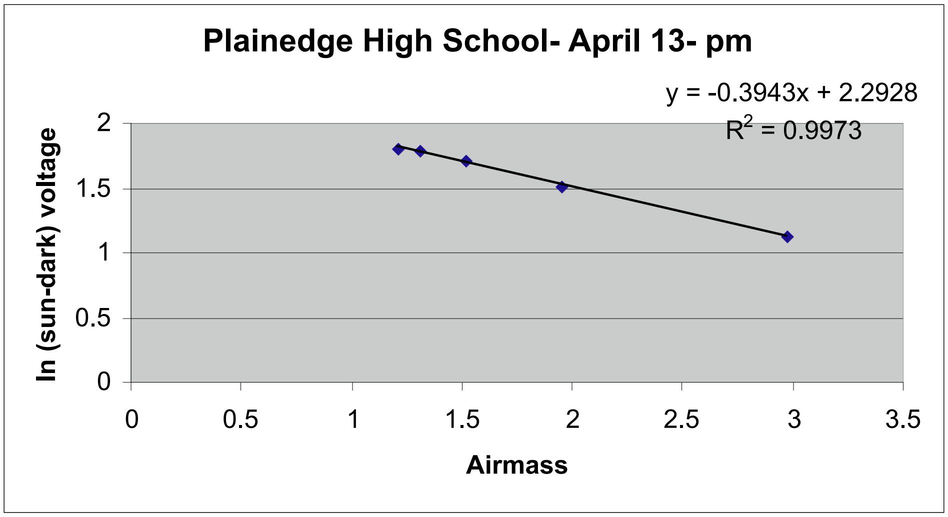
In addition, a filter was placed over the light aperture in every fifth sunphotometer to sharpen the blue cut off. It seems that the LED had a sharp red cut-off, but a very broad blue "wing" (the absorbency near the blue region was very broad). The filter decreased the overall transmission. By placing a filter in every fifth hand held, there was the hope that the voltages obtained from various solar intensities would be lowered with the decrease in energy shining on the LED. An Intensive Observation Period (IOP) was conducted from April 7th to April 25, where high school students made measurements. This was also an opportunity for students to become involved in scientific research. Time, date, and sun and dark voltages were recorded. Students made their measurements and the data was analyzed.

Limitations

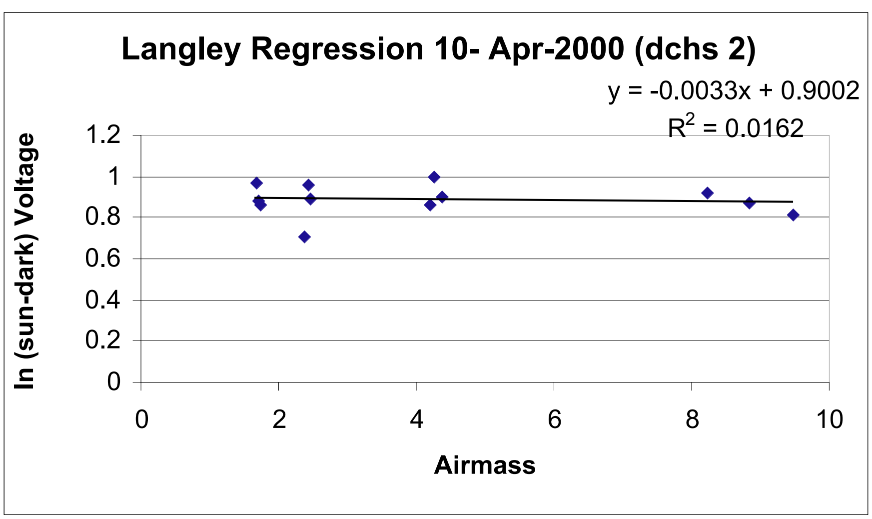
Firstly, the spreadsheet we used based the air mass calculations on the hour angle, time of day, pressure, latitude and longitude, and elevation. The hour angle is the difference between local solar time and solar noon, measured in degrees; every four minutes is one degree. We decided to make the elevation of all of the participating schools 0 km above sea level. However, the elevation of differing high schools across New York City is not the same. In addition, not sanding the LED would cause it to have more surface area, thereby interpreting a higher voltage than would be interpreted from a flattened LED. This poses problems because a little change in the position of a student's sunphotometer can mean a big change in the voltmeter. This can cause confusion among those who are taking measurements. Furthermore, the type of voltmeter may lead to some error as well. For the IOP, we used a Radio Shack multimeter, which gives a phantom reading when the power source of the electrical device (in our case, a sunphotometer) is off. For example, if while trying to get a dark reading, the power source is turned on, then off, and then quickly turned back on again, the voltmeter hovers around the true reading, but takes a while to get there. This might pose a little problem, but is worth mentioning.

Results

The optical thicknesses from the Langley regressions ranged from values that were impossible (e.g., 9.0) to results that were reasonable and very linear, but off by a factor of two or three for that day. For example, at Plainedge High School, a student received a value of .1 for tau and had a correlation coefficient of over 0.9.



This difference was probably not due to an inherent physical difference in the construction in of the sunphotometer, but due to the careful nature of the measurements made. Other school's values for the optical thickness ranged from very high tau's (2 or 3) to very low tau's like .003.



Some taus were even negative. As for the sunphotometers with filters, the data was just as variable as the data from the sunphotometers that did not have filters.

The results of the spectral response showed a slightly sharper peak for the unsanded LED, but the magnitude of the difference in the sharpness of the peaks are so small that such results do not rule out the sanded or unsanded LED as a practical and even useful measuring device. However, through use with sunphotometers that have a sanded and unsanded LED, the sanded LED has been proven more stable.

Conclusions

Since some students have retrieved robust Langley Regressions and reasonable values for tau suggest that the sunphotometers do work, but the student must be skilled in making measurements. Therefore, it would be profitable to change the instrument so that it is easier to use for all that participate in the study.

The first change that could be done to make the sunphotometer more usable is to sand the LED. Those who used hand helds with sanded LED's have commented on the absence of a drastic change of voltages when taking a measurement, as opposed to the wild fluctuations of the hand helds with unsanded LED's. Another modification is to increase the size of the aperture. We also need to test the individual components of the sunphotometer because it is possible that the tolerances of the electronics of some sunphotometers are better than others. Regarding the multimeter, the phantom reading seems only to hold for those readings that are taken in millivolts and not due to any autoranging multimeter.

Bibliography

Cassell, Andre, August 1997: Langley Regression and the Sunphotometer.
http://icp.giss.nasa.gov/research/aerosols/langley/

Reyes, Maricela, August 1997: Aerosols in the Atmosphere.
http://icp.giss.nasa.gov/research/aerosols/aeratm/

Russell, P.B. et. al, June 28-July 02 1999: North Atlantic Aerosol Properties and Direct Radiative Effects: Key Results From Tarfox and ACE-2.
http://geo.arc.nasa.gov/sgg/tarfox/whatnew/ExtendedAbs/AtlanTFX%26ACE2_AMSRadExtAbs.pdf